ON THE BIOLOGY OF AN ESTUARINE POPULATION OF GREY MULLET, *MUGIL CEPHALUS* L., IN NEGOMBO LAGOON, SRI LANKA.

by

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ABSTRACT.– *Mugil cephalus* L. in Negombo lagoon (7°10'N and 79°50'E), Sri Lanka, were observed to be non-intermittent spawners who spawn once during their spawning season which extends from October to November. In small length groups, males were more abundant but a 1:1 sex ratio was attained with growth. The mean lengths at maturity were 33.7 cm and 37.0 cm for males and females respectively. The fecundity ranged from 0.71×10^6 to 1.7×10^6 for fish ranging in size from 34 cm to 46 cm. The relative gut length which varied from 3.52 to 5.14 did not change significantly with size. The main food item of the fish above 10 cm in total length was serpulid polychaetes. Composition of the diet did not change significantly with growth.

RÉSUMÉ.– *Mugil cephalus* L., de la lagune Negombo (7°10'N et 79°50'E), au Sri Lanka, est un poisson dont la ponte ne se fait qu'une seule fois au cours de la saison de ponte (octobre à novembre). Dans les petites classes de tailles, les mâles sont plus abondants mais un sex ratio de 1:1 est atteint lorsque l'âge augmente. Les longueurs moyennes à la maturité sexuelle sont de 33.7 cm et 37.0 cm pour les mâles et les femelles, respectivement. La fécondité varie de 0.71×10^6 à 1.7×10^6 pour des poissons de 34 à 46 cm de longueur. La longueur relative du tube digestif, qui varie de 3.52 à 5.14, ne change pas avec la taille de manière significative. Les proies principales des poissons d'une taille supérieure à 10 cm de longueur totale sont des Polychaetes Serpulidés. La composition du régime alimentaire ne varie pas significativement avec la croissance.

Keywords : Mugilidae, *Mugil cephalus*, Sri Lanka, Reproductive biology, Food, Feeding.

The grey mullet, *Mugil cephalus* L., has been identified as a very important species in the brackish water fisheries of tropical and subtropical regions throughout the world. Its importance and extensive distribution has stimulated research on its biology in various regions of the world (Thomson, 1966 ; Pillay, 1972 ; De Silva, 1980 ; Oren, 1981). In Sri Lanka, some aspects of the biology of young stages and the reproductive biology of adults has been described (De Silva and Perera, 1976 ; De Silva and Wijeyaratne, 1977 ; De Silva and Silva, 1979 ; Perera and De Silva,

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1978a, b ; Silva and De Silva, 1981). In this paper, the reproductive biology, food and feeding of *M. cephalus* in Negombo lagoon (7°10'N and 79°50'E), a tropical lagoon on the west coast of Sri Lanka, are described as a complement to the existing information on the biology of this grey mullet species.

MATERIALS AND METHODS

Live specimens of *M. cephalus* were obtained from the fishermen from January 1980 to December 1982 and were immediately preserved in ice for further analysis. In the laboratory the total and standard lengths were measured to the nearest mm and fish were weighed to the nearest 0.01 g; the fish were dissected and their maturity stage recorded. The gonads were removed and weighed to the nearest 0.1 mg to calculate the gonadosomatic index. The mature ovaries were preserved in Gilsons fluid for one week and the fecundity was estimated by subsampling gravimetrically (Lagler, 1956). The diameter of the eggs in mature ovaries was determined using a graduated micrometer eye piece. The length of the intestine was measured to the nearest mm and relative gut length was calculated. The stomach contents were weighed to the nearest 0.1 mg to determine the gastrosomatic index. The stomach contents were then examined under an optical microscope and identified as far as possible. The quantitative analysis of stomach contents was done by the method described by Helawell and Abel (1971). In this analysis, a cell of *Pinnularia*, a common diatom species occurring in the diet was considered as an unit. The similarity among the diets of different size groups was determined by the method described by Schoener (1970).

RESULTS AND DISCUSSION

Reproductive biology.

Four developmental stages of gonads were identified in *M. cephalus* during the present study. They are virgin, developing, developed and mature stages. Fish in spawning and spent stages were not found in the lagoon catches. In the virgin stage, the gonads are thread like and the sex could not be distinguished. Brulhet (1975) reported that the ovaries and testes could not be distinguished at this stage even microscopically. The ova were visible in the ovaries of the other 3 stages. The gonads extended at the developing and developed stages for 1/3 and 1/2 the length of the body cavity respectively, and at the mature stage, they extended for about 2/3. At this latter stage some of the eggs are translucent.

In the mature ovaries, eggs of two size groups were observed (Fig. 1). One group represented developing oogonia while the other consisted of mature oocytes. Similar observations have been made for this species by several workers (Abraham *et al.*, 1966, Timoshek and Shilenkova, 1974 ; Grant and Spain, 1975 ; Kuo and Nash, 1975 ; Rangaswamy, 1975). This distribution pattern of developing eggs in

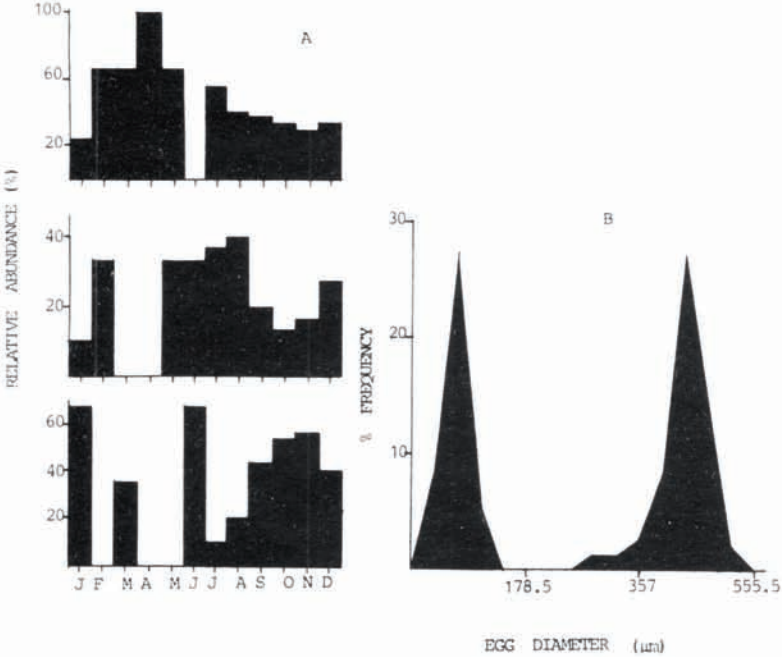

Fig. 1.– (A) Seasonal variation of relative abundance of virgin, developing and mature individuals. (B) Percentage frequency distribution of egg diameters.

M. cephalus indicates that they are non-intermittent spawners, who spawn only once during the spawning season (Bruslé, 1981a), although Silva and De Silva (1981) suggested that they are multiple spawners. The diameter of mature oocytes ranged from 286 µm to 500 µm, with a modal value of 428 µm. These values are smaller than those recorded for this species from Israel (Abraham *et al.*, 1966).

The gonadosomatic index (GSI) of virgin fish never exceeded 0.02. The GSI of males was always smaller than that of females, and about 2 % of the body weight even in the mature stages. However, it has been reported that in some *M. cephalus* from Japanese waters, the testes are about 11 % of the body weight (Bruslé, 1981a). In mature females, GSI ranged from 10.23 to 12.80. Values in this range have been recorded in Israel (Shehadeh, Kuo and Nash, 1973), while higher values have been reported from New Zealand (Grant and Spain, 1975).

GSI is widely used to determine the breeding season of fish. The GSI of *M. cephalus* in Negombo lagoon was found to be high in October/November (Fig. 2), as well as this, the percentage of mature individuals in the population was high (Fig. 1). The main spawning period of this species therefore appears to be October and November. The observations of Silva and De Silva (1981) also agree with these results. In India, *M. cephalus* has been reported to spawn from October to May (Gopalakrishnan, 1974). The spawning season of this species appears to differ from region to region (Bruslé, 1981a). A single spawning season per year has been reported in

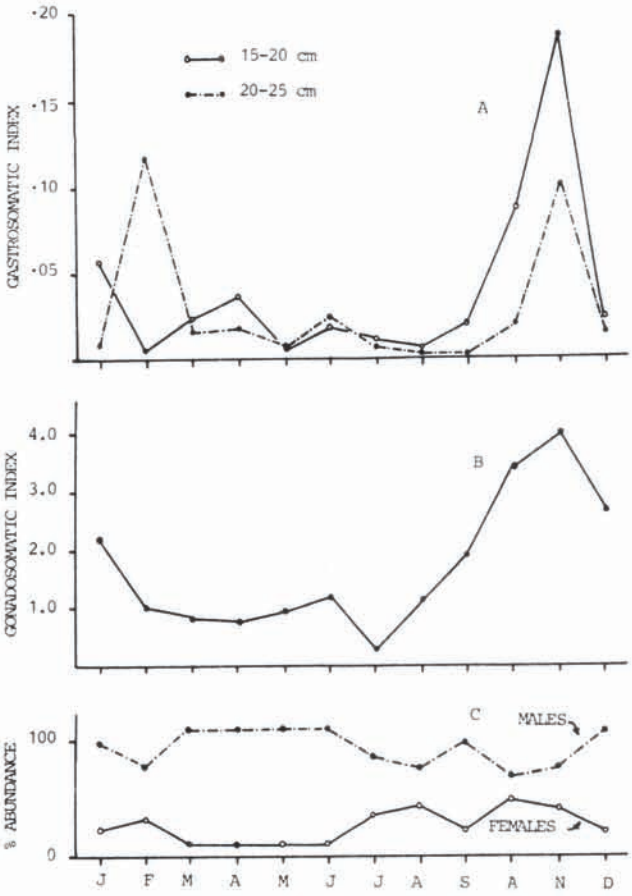

Fig. 2.– Seasonal variation of gastrosomatic index (A), gonadosomatic index (B) and percentage abundance (C) of males and females of *M. cephalus* in Negombo lagoon.

other grey mullet species, for example *Aldrechetta forsteri* (Thomson, 1957), *Mugil auratus* (Avanesov, 1972), *M. capito* (El Maghraby *et al.*,1974). *M. chelo* (Hickling, 1970), *M. cunnesius* (Gopalakrishnan, 1974), *M. curema* (Moore, 1975) and *Liza macrolepis* (Luther, 1968).

Statistically significant correlation coefficients between GSI and environmental parameters such as pH, salinity, water temperature and rainfall were not observed for *M. cephalus* in Negombo lagoon (Table I). Generally, most fish in tropical regions spawn during the rainy season which enables their young to grow in optimal environmental conditions. During this period, the wind speed is also high resulting in a thorough mixing of water. This mixing, together with fairly high tropical temperature, results in a high growth of algae, followed by an abundance of zooplankton which is an important food source for young. Negombo lagoon receives most of its rain from May to November, due to south west monsoons. Therefore, spawning of *M. cephalus* appears to coincide with this rainy season.

Table I.– Correlation coefficients of mean gonadosomatic index and gastrosomatic index with environmental parameters. (* indicates the values which are significant at 50 % level).

	Temperature	Salinity	pH	rainfall
Gonadosomatic Index	0.2304	– 0.5159	0.3560	0.5610
Gastrosomatic Index				
15-20 cm fish	– 0.334	– 0.462	0.056	0.668 *
20-25 cm fish	– 0.362	– 0.090	0.210	0.232

Spawning stage individuals were not found in the lagoon indicating that they do not spawn in brackish waters. *M. cephalus* has already been identified as a marine spawning species (Brulhet, 1975). Since spent fish were not found present in the lagoon catches, they may be spawning far off the coast, and may not return to the brackish water environment after reproduction.

The sex ratio of the *M. cephalus* population was highly unbalanced in favour of males, they constituted 79 % of the population. The male to female ratio was approximately 4: 1. However, the overall sex ratio recorded by Silva and De Silva (1981) for the same population is 1:1. The reason for this difference may be that their biased sampling technique where they have analyzed the fish collected from one type of gear, the bursh parks which contributed only for 36.5 % of the total landings of the whole lagoon. Higher ratios of males to females have been recorded for *M. cephalus* from Australia (Kesteven, 1942), Hawaii (Peterson and Shehadeh, 1971), and Mauritania (Brulhet, 1975). It is possible that the males are more active and get caught in the gear in higher numbers, resulting in an unbalanced sex ratio, as observed. In addition there can be sex differences in size and age. If males mature early they may die early; in older age groups the percentage of females may be higher. Brulhet (1975) has observed in *M. cephalus* populations, that there can be sex separation in spawning migrations and this must also result in an unbalanced sex ratio.

During the act of spawning in *M. cephalus* it has also been observed that one female is surrounded by several males (Breder, 1940; Arnold and Thomson, 1958). Therefore, the total number of males in a population may actually be higher than that of females.

Although the males out-numbered the females throughout the year, during the breeding season males were relatively less abundant in the lagoon, than in other months (Fig. 2). The reason for this may be that more males have migrated to spawning areas.

The sex ratio was found to vary with size (Fig. 3). In the shorter length groups, the males were more abundant, but as they grow a 1:1 sex ratio is attained. This indicates that males in the population mature earlier and die sooner than the females. This is further evident from the minimum size of maturity of the two sexes (Fig. 3). The males start maturing at a length of about 22 cm and at 38 cm, all the males in the population are mature, resulting in a mean length of 33.7 cm at 50 % maturity. The females start maturing at a length of about 32 cm and all the individuals in the population are mature at 40 cm. This results in a mean length of

37 cm at 50 % maturity. Therefore, since males mature earlier than females, it is possible that they have shorter lives resulting in a decreased number of males in larger length groups. Most of the literature shows that the males of *M. cephalus* populations mature earlier, at a smaller size, than the females (Broadhead, 1958 ;

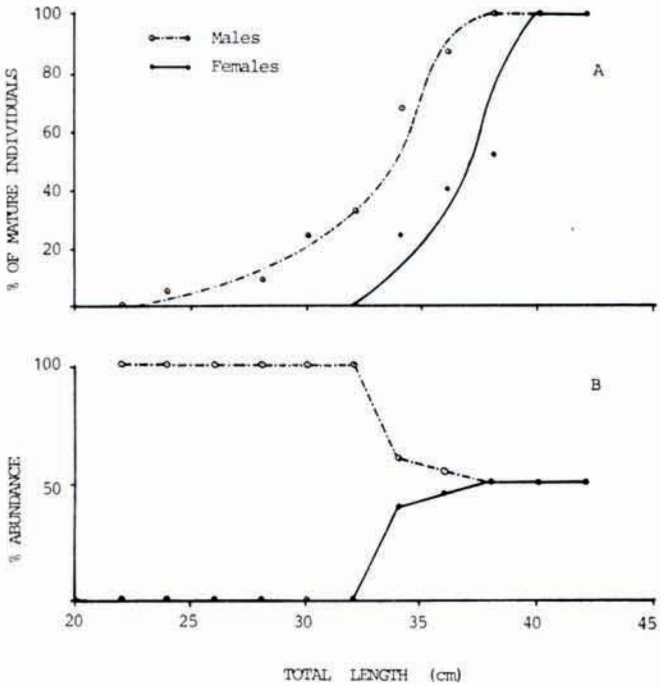

Fig. 3.– Variation of percentage of mature individuals (A) and percentage abundance of males and females with the total length (B).

Stenger, 1959 ; Arnold and Thompson, 1958 ; Erman, 1959 ; Kesteven 1942 ; Thomson, 1957 ; Brulhet, 1975 ; Ochiai and Umeda, 1969). *M. cephalus* from Mexico, Egypt, Black sea, Australia, Mauritania and Japan have been observed to mature at a bigger size than those in Negombo lagoon (Bruslé, 1981a). Negombo lagoon is closer to the equator, where the annual mean temperature is higher. This could be the reason for the relatively smaller size at which first maturity is attained in Negombo lagoon. Linder *et al.* (1975) have observed that *M. cephalus* from Texas bay, U.S.A., reaches maturity at 16 cm; this is smaller than the value recorded in this study. They attribute this small size to thermal effluents that are discharged into that region.

The fecundity of *M. cephalus* in Negombo lagoon ranged from 0.71×10^6 to 1.7×10^6 for fish ranging in size from 34 cm to 46 cm. In fish of 56 cm, Silva and De Silva (1981) observed it to be as high as 4.8×10^6. Statistically significant relationships of fecundity with body weight and standard length were found. The relationship with length was curvilinear while that with weight was linear. These relationships are given below :

$F = 1789.87\,W + 30956.5$

$F = 57.51\,L^{2.86}$ where F = Fecundity; W = body weight in g; L = Standard length in cm.

Similar relationships have been calculated by Grant and Spain (1975) and Silva and De Silva (1981). The rate of increase of fecundity with body length recorded here is higher than that observed by Silva and De Silva (1981). It has been suggested that the relationship of fecundity with body weight can be used to discriminate between the different stocks of the same species of grey mullets due to the variable rates in different localities (Alvarez-Lajonchere, 1981). The relative fecundity was found to vary from 1757 to 1955 per g of body weight with a mean value of 1842. This was higher than that recorded for *M. cephalus* from Hawaiian waters (Shehadeh, Kuo & Milisen, 1973). The relationship between relative fecundity and body size was not found to be statistically significant. However, in *M. capito*, significant increase of relative fecundity with size has been observed by El Maghraby *et al.*, (1974).

Food and feeding.

The relative gut length varied from 3.52 to 5.14. However, a significant change of it with standard length was not observed. There was also no significant change in the amount of plant and animal matter in the diet as the fishes length increases. However, Blaber (1976) observed that in *M. cephalus*, the relative gut length increased significantly with size, although the composition of the diet of smaller and larger fish was similar.

In the stomach contents of *M. cephalus*, 17 genera of diatoms, 3 genera of green algae, 3 genera of blue green algae, 3 genera of dinoflagellates, sand particles, serpulid polychaetes and crustaceans were present (Table II). Seasonal variation of food items in the diet of fish in 15-20 cm and 20-25 cm length groups is graphically shown in Fig. 4. In fish measuring 15-20 cm, serpulid polychaetes were the most important food item throughout the year except in May, June and November when detritus was more abundant. In fish of 20-25 cm length group, serpulid polychaetes were the most abundant food type in all months, except in December, when sand particles constituted the major portion of the stomach contents.

Mean relative abundance of major gut components is shown in Fig. 5. Detritus was the major gut component in the 5-10 cm size group while in other groups serpulid polychaetes were more abundant. However, statistically significant changes in the composition of these fishes diet with length, was not observed.

The food of *M. cephalus* has been extensively studied due to the economic important of this species (Luther, 1962; Thomson, 1966; Odum, 1970 and Blaber, 1976). Food items similar to those observed in the present study have been recorded in the diet of grey mullets from Swartkops estuary in South Africa (Massen and Marias, 1975). Generally, most of the grey mullets have been found to feed on organic detritus, diatom and green algae (Fagade and Olaniyan, 1973; Blaber, 1976).

The composition of the diet in grey mullets from different localities differs depending on the abundance and types of food organisms present (Buslé, 1981b). The diet also varies with age and size. When the fishes are less than 30 mm, they are carnivorous, feeding on mosquito larvae, copepods and zooplankton (Odum,

Table II.– Food items present in the stomach contents.

	5-10 cm	10-15 cm	15-20 cm	20-25 cm	above 25 cm
Blue Green algae:					
Anabaena		+	+	+	
Lyngbia			+	+	
Merismopedia		+	+	+	
Green algae :					
Chladophora		+	+	+	+
Closterium			+		
Spirogyra	+	+	+	+	
Diatoms :					
Amphora	+		+	+	+
Achnanthes				+	+
Cocconeis	+	+	+	+	+
Coscinodiscus	+	+	+	+	+
Cyclotella	+	+	+	+	
Cymbella	+		+	+	
Diatoma		+		+	+
Diploneis			+	+	
Gramatophora		+	+	+	+
Licmophora		+	+	+	+
Melosira		+	+	+	+
Navicula	+	+	+	+	+
Nitzchia	+	+	+	+	+
Pinnularia	+		+	+	+
Pleurosigma		+		+	+
Prorocentrum		+	+		
Tabellaria		+	+	+	
Dinoflagellata :					
Ceratium		+	+	+	
Gymnodinium		+		+	
Péridinium		+	+	+	
Crustacea :					
Cladocerans			+	+	
Copepods				+	
Unidentified crustaceans		+	+		
Nauplii			+		
Serpulid polychaetes	+	+	+	+	+
Detritus	+	+	+	+	+
Sand	+	+	+	+	+

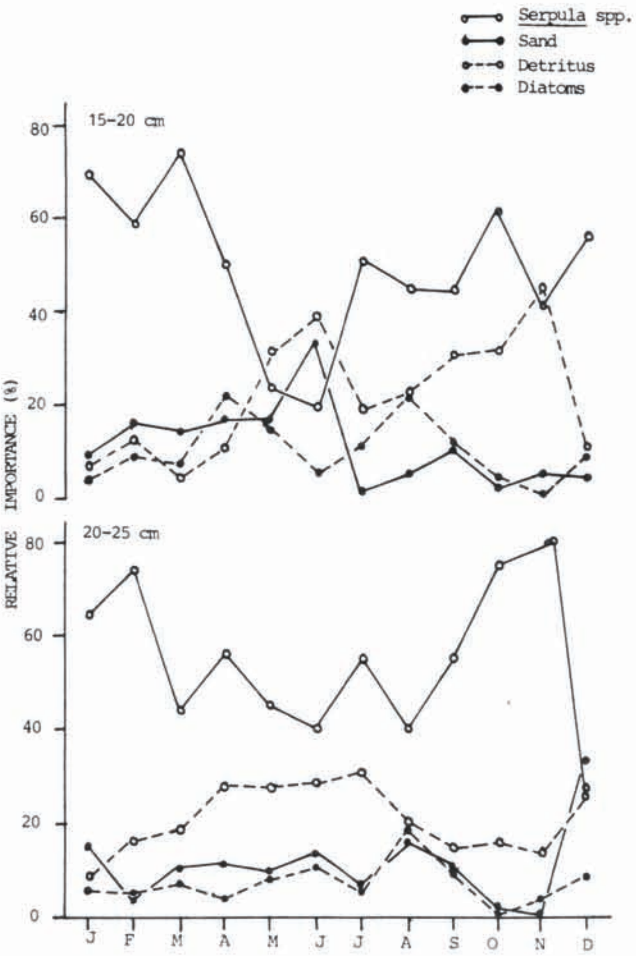

Fig. 4.– Seasonal variation in the relative importance of major groups of food items of *Mugil cephalus.*

1970). The juveniles feed on plankton and obtain their food from the water column (Odum, 1970 ; Hickling, 1970) during diurnal migrations. As they grow their feeding habit gradually changes from a planktonic filter feeding habit to a benthic grazing habit (Blaber and Whitfield, 1977). In Negombo lagoon, this transition occurs when they are between 20 and 50 mm (De Silva and Wijeyaratne, 1977). All the fish analysed in the present study were above 50 mm. At this size they have normally changed their feeding habit to a more benthic grazing form, feeding mainly on detritus and bottom living serpulid polychaetes.

The sand particles ingested are thought to be helpful in the grinding of food particles in the thick walled pyloric stomach, which acts as a gizzard (Thomson, 1966). These particles are filtered through a pharyngeal filter apparatus (Thomson, 1966). Odum (1968) suggests that *M. cephalus* selects fine sand particles and they prefer sand particles which are rich in absorbed, or covered, organic material, bacteria and protozoa. Similarly these are considered as a good source of vitamin B_{12} for grey mullets (Vallet *et al.*, 1970).

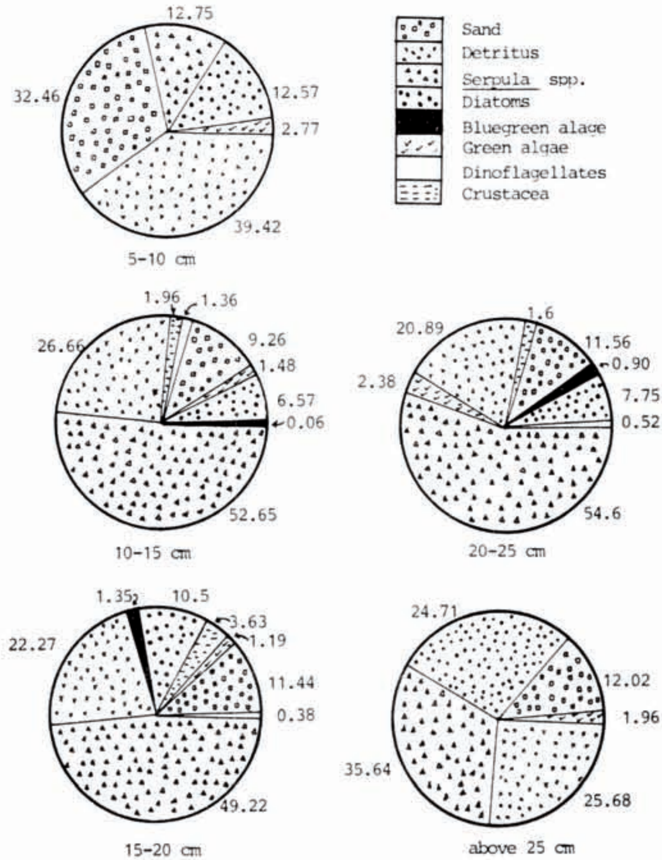

Fig. 5.– Relative importance of major groups of food items in the diet of *M. cephalus*.

Table III.– Similarity indices among the diets of different size groups.

	5-10 cm	10-15 cm	15-20 cm	20-25 cm	>25 cm
5-10 cm	100	57	58	55	65
10-15 cm	–	100	91	93	79
15-20 cm	–	–	100	93	81
20-25 cm	–	–	–	100	78
>25 cm	–	–	–	–	100

Similarity indices among the diets of different size groups are shown in the Table III. The percentage of overlap of the diet in the 5-10 cm size group with those of other groups is relatively low. The main reason for this is the high amount of detritus and relatively low amount of serpulid polychaetes in the diet of individuals

in the 5-10 cm size group. In other groups, serpulid polychaetes were the most abundant item. The similarity indices for the diet of these size groups were above 78 %. However, intraspecific competition for food may not occur, since it is abundant in the highly productive lagoon environment.

Seasonal variation in the gastrosomatic index (Fig. 2) shows that *M. cephalus* does not feed at the same intensity throughout the year. High intensity of feeding was observed in October and November, for fish measuring 15-20 cm, while in 20-25 cm fish it was high in February and November. In the former group a significant increase is the intensity of feeding, with increased rainfall, was observed (Table I).

Since grey mullets feed on both living organisms and detritus, they occupy an important position in the trophic structure of a community. Odum (1968) suggests that food does not appear to be a limiting factor for grey mullet and they seem to have little competition for food from other fish species.

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